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Evaluating the Concentration of Pb, Hg, Co, V, As, Fe, Cu, Cd, Cr, Mn, Ni, and Zn and their Potential Sources in Soil from Two Abattoirs in Itu and Ikot Ekpene Local Government Areas of Akwa Ibom State, Nigeria

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ABSTRACT: Inorganic contaminants which consist of toxic metals and salts are notable for their wide environmental dispersion and their tendency to accumulate in the tissues of the human body. Heavy metals are the major inorganic contaminants in abattoir soils. These metals, even at relatively low concentrations, are toxic. Hence the objective of this paper was to determine the concentration of Pb, Hg, Co, V, As, Fe, Cu, Cd, Cr, Mn, Ni, and Zn and their potential sources of pollution in soil from two abattoirs in Itu and Ikot Ekpene Local Government Areas of Akwa Ibom State, Nigeria using appropriate standard methods after the dry oxidation. The concentrations of heavy metals were determined using an atomic absorption spectrophotometer (AAS). The distribution of heavy metals contaminants in the Itu abattoir was of the order Hg < As < V < Cr < Co < Mn < Ni < Pb < Cd < Cu < Zn < Fe, while that of the Ikot Ekpene abattoir was Hg < As < Co < V < Cr < Mn < Pb < Ni < Cd < Cu < Zn < Fe. The mean order obtained for both abattoirs was Hg < As < V < Cr < Co < Mn < Ni < Pb < Cd < Cu < Zn < Fe. The results were subjected to some pollution indices to ascertain the level of ecological impacts on both plants and animals ecosystem around the abattoirs. The contamination factor, geo-accumulation index, degree of contamination, and pollution load index depict no pollution. Generally, all metals investigated were below the permissible limits of DUTCH, FEPA, WHO/FAO, and NESREA.

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Abattoirs are premises approved and registered by regulating authorities for safe and hygienic slaughtering, inspection, processing, effective preservation, and storage of meat products for human consumption (Vershima *et al.*, 2015). Nwanta *et al.* (2008) reported approximately 30 abattoirs, 132 slaughterhouses, and 1077 slaughter slabs in Nigeria, collectively possessing a total annual slaughter capacity of about 14,127,868 animals. Dan *et al.* (2018), in their study, identified 8 major abattoirs in Akwa Ibom State. Heavy metals are metallic elements characterized by their high density, atomic weight, and potential toxicity. Although most of the heavy metals are useful, some, even at low concentrations can cause serious health problem to both plants and animals in ecosystem (Etuk *et al.,* 2023a & b; Nwokem *et al.,*

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2023; Okon *et al.,* 2023a & b; Anweting *et al.,* 2024; Ebong *et al.,* 2024). The toxicity of these metals does not only depend on their total concentrations but also on the bioavailable quantities, which is dependent on numerous factors like pH, organic matter contents, temperature, etc. Heavy metals are used in making metal alloys and pigments for paints, cement, paper, rubber, and other materials (Lenntech, 2010). They are also used for carbohydrate and lipid metabolism and the utilization of amino acids (Asio, 2009). Also, heavy metals help in the production of red blood cells in the body and are used as an ingredient in steel and other metal products (Asio, 2009; Lenntech, 2010). Heavy metals, due to their persistence, can lead to the accumulation and biomagnification in certain organisms, resulting in greater exposure levels than what naturally occurs in the environment (Adelekan and Abegunde, 2011). Soil is a non-renewable natural resource that is essential for the health and functioning of terrestrial ecosystems (Sánchez-Castro *et al.*, 2023). It is the uppermost layer of the earth's crust that supports plant growth and provides a habitat for various organisms. It is a complex mixture of mineral particles, organic matter, water, air, and living organisms. They are formed as a result of the weathering and degradation of rocks and minerals over a long period of time. Contamination of soil often results in the accumulation of heavy metals in the soil, and sludge cake. Oil spillage, animal droppings, firewood firing filth, fertilizer application, pesticides, deposition of waste with high metallic contents, mine tailings, and pollutants released from different manufacturing industries are some of the major sources of soil contamination and they have adverse effect on environment and ecosystem (Eddy *et al.*, 2006; Aires *et al.*, 2013).

Numerous activities taking place in abattoirs could contaminate the environment directly or lead to indirect impacts, such as the transportation of toxic waste to nearby water bodies (Abubakar and Tukur, 2014). The nature of abattoir wastes and effluents varies from day to day depending on the number, types of stock being processed, and processing method. Every day across the rural and urban markets in Nigeria, animals are slaughtered, and their meat is sold to the public for consumption (Neboh *et al.*, 2013). These activities surely generate waste, which, if not properly managed or regulated, becomes a problem to the soil. Nigeria seems to suffer from an inadequate waste management strategy in all public abattoirs, such that large amounts of solid waste and untreated effluents are prevalent. Evaluating the heavy metal concentration in the soil around abattoir vicinities is crucial for understanding the extent of environmental contamination and potential health hazards for nearby communities. Olarewaju and Olufayo (2014) reported that different organs of cattle, such as muscle, blood, liver, kidney, viscera, and hair, have been found to contain heavy metals such as lead (Pb), copper (Cu), iron (Fe), arsenic (As), and chromium (Cr). Rabah *et al.* (2010) opined that some body parts of animals can release heavy metals into the soil and can also increase the pH of the soil. A significant amount of waste is generated from various activities in abattoirs, including animal slaughter, washing of paunch, animal skin removal or trimming, singeing of hide, a clean-up operations e.t.c. (Neboh *et al.*, 2013; Useh *et al.*, 2015), disposal of this waste is the major challenge that slaughtering sector are facing (Osu & Okereke, 2015).Generally, abattoir wastes comprise a wide range of components, including grease, feathers, fat, paunch manure, shingle, whole grains, undigested feed, cellulose fiber, blood, long hairs, bones, large plant fragments, undigested protein, organic solids, inorganic solids, salts, chemicals added during processing operations, urine, aborted foetus, excess nitrogen from digested protein, mucus, residues from digested fluids, bacteria, worn-out cells from intestinal linings, as well as waste minerals or metals and non-metal ions such as iron, calcium, magnesium, phosphorous, sodium, etc. (Osu and Okereke, 2015; Dan *et al.*, 2018; Ebong *et al.*, 2020). Abattoir wastes have the potential to reduce soil fertility and productivity. However some farmers in Nigeria have adopted abattoir waste as organic manure for the cultivation of edible plants on their farms. This may result in the transfer of heavy metals present in the abattoir waste to other plants and animals (including humans) through the food chain. Hence, the objective of this paper was to determine the concentration of Pb, Hg, Co, V, As, Fe, Cu, Cd, Cr, Mn, Ni, and Zn and their potential sources in soil from two abattoirs in Itu and Ikot Ekpene Local Government Areas of Akwa Ibom State, Nigeria.

MATERIALS AND METHODS

Description of the Study Areas: Itu Local Government Area is located in Akwa Ibom State, in the south-south region of Nigeria. It spreads over an area of about 34 km^2 (Obianwu *et al.*, 2011), with an estimated population of 127,856 according to the 2006 census (City population.de, n.d.). Itu L.G.A. has coordinates 5°12' 4.72" N and 7°59' 1.43" E of the Greenwich meridian. The area is predominantly characterized by farmlands and forests with hot and humid climatic conditions that are regulated by two seasons: the wet season spanning from March to October and the dry season from November to April (Obianwu *et al.*, 2011). Ikot Ekpene, also known as Raffia City, is a historic town in the south-southern State of Akwa Ibom. The city lies between latitudes 5.072°–5.140°N and longitudes 7.390°–7.458°E in Akwa Ibom State, South south Nigeria. It spreads over an area of about 116 km^2. The area has a population of 141,408 according to the 2006 census. The vegetation in the study area is of the rain forest type. It is sustained by a tropical climate characterized by high temperatures, with an annual mean of 5.5°C–6.5°C. The maximum daily temperature lies between 28°C and 30°C during March, and the minimum daily mean temperature lies between 23°C and 24°C during July and August (George *et al.*, 2010). High relative humidity (annual mean of 83%) and high precipitation (250mm per annum) are prevalent in the area. The area is geologically characterized by coarse-grained sand and gravelly sands with minor intercalation of clays and shales from top to bottom, respectively.

Fig 1: Location of sampling stations on the map of Akwa Ibom, Nigeria

Chemicals and Apparatus: All chemicals used in this research were analytical grade reagents.

Analysis of the Sample: Digested samples were analyzed for the levels of Pb, Hg, Co, V, As, Fe, Cu, Cd, Cr, Mn, Ni and Zn using an atomic absorption spectrophotometer (GBC XplorAA Dual, ACN005472686, made in the United Kingdom) at the AKS MST-RD Laboratory, Ministry of Science and Technology, No. 84 Obio Imo Street, Uyo, Akwa Ibom State.

Sampling: All samples were collected randomly within the study areas. Three composite soil samples were collected from two abattoir vicinities located in Itu and Ikot Ekpene Local Government Area respectively. A control soil sample was also collected from Nwaniba, Uyo, Akwa Ibom State. The samples were packed in well-labeled sample bottles, and conveyed to the laboratory for preparation and analysis.

Sample Preparations: Soil samples were air-dried to constant weight at room temperature to remove moisture from the sample and then oven-dried at 60°C for one hour to fully remove moisture. Soil samples were then ground using a mortar and pestle and sieved with a mesh of 2 mm in diameter to remove stones and debris. The sample (0.5g) was measured out into a 250 ml beaker using an analytical weighing balance, and 0.5 ml of concentrated nitric acid was added directly to the soil sample and stirred. One hundred milliliters of distilled water was added and stirred. The mixture was then heated to evaporate below boiling point using a heating mantle placed inside a fume cupboard until the volume was reduced to 20 ml and allowed to cool. The mixture was then filtered using Whatman No. 42 filter paper into a 100 ml volumetric flask, and distilled water was added up to mark. Heavy metal concentration was determined using an atomic absorption spectrophotometer.

Preparation of Calibration Standards: For calibration of the instruments, a blank solution and a series of 3 standard solutions were prepared by serial dilution of the stock standard solutions (1000 mg/l) of the metals to be analyzed. Standard methods of the American Society for Testing and Materials (ASTM) 2010 was employed for the preparation of standards used for calibration. The same method was used in the preparation of standards for all the metals analyzed.

Heavy Metal Analysis for the Soil Samples: Pollution assessment: Mazurek *et al.* (2017) highlighted the significant role of pollution indices in conducting a comprehensive assessment of soil pollution levels. These indices serve as valuable tools for evaluating the extent of soil contamination. Four major geochemical indices—contamination factor (CF), geo-accumulation index (Igeo), degree of contamination (Cdeg), and pollution load index (PLI) were considered for this study to assess the pollution level based on toxic metal concentrations in the soil samples.

Contamination factor (CF): is a metric used to determine the degree of contamination or pollution in a given sample. The contamination factor of the sample was calculated using the general equation highlighted euation1.

$$CF = \frac{\text{Cm}}{\text{Bm}} \quad (1)$$

Where CF is the contamination factor, Cm is the concentration of the metal in the studied sample, and Bm is the background concentration of metal either from literature (average crustal abundance) or directly determined from a geologically similar area.

Hakanson (1980) categorized the contamination factor into various classes, which are as follows: CF < 1 - Low contamination; 1 < CF < 3 - Moderate contamination; 3 < CF < 6 - High contamination; 6 > CF - Very high contamination.

Geo-accumulation index (I_{geo}): Muller (1969) introduced the geo-accumulation index (I_{geo}) as a tool to quantify metal pollution levels in soil and aquatic sediments. This index is effective in the assessment of the degree of metal accumulation. The geo-accumulation index (I_{geo}) for soil samples was calculated using the equation 2:

$$I_{geo} = \log_2 \frac{\text{Cn}}{1.5\text{Bn}} \quad (2)$$

Where I_{geo} is the geo-accumulation index, Cn denotes the concentration of the metal in the sample, Bn denotes the background concentration of the same metal, and factor 1.5 is the background matrix correction factor due to lithogenic effects (Kowalska *et al.*, 2016; Gasiorek *et al.*, 2017). Muller (1969) grouped the calculated values of I_{geo} into 7 classes as follows: Class 0 = $I_{geo} \leq 0$: Uncontaminated; Class 1 = $0 < I_{geo} < 1$: From uncontaminated to moderately contaminated; Class 2 = $1 < I_{geo} < 2$: moderately contaminated; Class 3 = $2 < I_{geo} < 3$: from moderately contaminated to strongly contaminated; Class 4 = $3 < I_{geo} < 4$: strongly contaminated; Class 5 = $4 < I_{geo} < 5$: from strongly to extremely contaminated and Class 6 = $I_{geo} > 5$: extremely contaminated

Degree of contamination (Cdeg): The degree of contamination (Cdeg) is simply the sum of all the contamination factors of heavy metals for a particular abattoir soil and was determined using an equation as reported by Sayadi *et al.* (2015) and Pekey *et al.* (2004). The degree of contamination at each location was calculated as in equation3:

$$C_{deg} = \sum \text{CF} \quad (3)$$

Where CF denotes the contamination factor for all the studied metals at a particular location.
The four classes of C_{deg} as highlighted by Kowalska *et al.* (2016) are as follows: $C_{deg} < 8$ = low degree of contamination; $8 < C_{deg} < 16$ = moderate degree of contamination; $16 < C_{deg} < 32$ = considerable degree of contamination and $32 < C_{deg}$ = very high degree of contamination

Pollution load index (PLI): PLI is also used for the total assessment of the degree of contamination in soil. This index provides an easy way to prove the deterioration of the soil conditions as a result of the accumulation of heavy metals (Varol, 2011; Simeon and Friday, 2017). The equation based on the procedure of Tomlinson *et al.* (1980) was employed to calculate the pollution load index (PLI) of heavy metals for each abattoir.

$$PLI = \sqrt[n]{\text{CF1 x CF2 x CF3 ... x CFn}} \quad (4)$$

Where CF denotes the contamination factor for the metals at each location and n is the number of analyzed heavy metals.
The different categories of PLI are as follows: PLI < 2: No pollution, 2 < PLI < 3: Heavy pollution and 3 < PLI: Extremely heavy pollution

RESULTS AND DISCUSSION

Heavy Metals Distribution in the Studied Soils: The summary of heavy metal concentration in the Itu and Ikot Ekpene abattoirs are presented in Table 1. From the data presented in the Table 1, the observed concentration of Fe was 41.214 mg/kg and 28.305 mg/kg for Itu and Ikot Ekpene abattoirs, respectively. The CV of 26.261% shows a moderate variation between both abattoirs. The mean concentration of 34.760±9.128 mg/kg was higher than 17.144 mg/kg obtained from the control plot but lower than the 623.88 mg/kg obtained by Ebong *et al.* (2020). Useh & Dauda (2018) suggested that contamination of the environment by Fe is also caused by natural sources and is not limited to waste materials like abattoir waste alone. This can be confirmed by the high amount of Fe (17.114 mg/kg) recorded in the control plot. Among the elements analyzed, the average value of Fe was the highest. The values obtained were lower than the 400 mg/kg recommended by FEPA and NESREA. The elevated value of Fe in the abattoir soil can be attributed to the blood from the animals killed and also to the feeds of the livestock. The result also revealed Pb concentrations of 2.422 mg/kg and 1.835 mg/kg in the Itu and Ikot Ekpene abattoirs, respectively. The result showed a slight variation of 19.501% between the values of both abattoirs. The average concentration was 2.129±0.415 mg/kg, which was higher than the value for the control plot (0.862 mg/kg). This indicates that activities in the abattoir contribute to the increase in the value of Pb in the abattoir soils. The mean result obtained was higher than 0.910±0.280 mg/kg obtained by Etuk *et al.* (2021) but lower than 15.00–30.80 mg/kg obtained by Ogunlade *et al.* (2021) in a similar study. The mean value obtained was lower than the 85 mg/kg recommended limits of DUTCH and FEPA. Possible sources of Pb stem from improper disposal of lead-containing materials (example, batteries), automobiles within the abattoir, and even contaminated feeds. The concentrations of Cu in both abattoir soils were 6.187 mg/kg and 5.216 mg/kg for Itu and Ikot Ekpene, respectively. The observed 12.042% CV shows a slight variation between values from both abattoirs. The mean concentration observed was 5.702±0.687 mg/kg. Though higher than the 0.05–1.70 mg/kg reported by Osu & Okereke (2015), it was within the range of 4.70±1.27–9.57±2.86 mg/kg observed by Simeon & Friday (2017). The mean value was greater than 3.927 mg/kg obtained in the control plot but less than the 36 mg/kg recommended by FEPA and DUTCH. Mercury had the lowest value of 0.001 mg/kg for both abattoirs. This value was lower than the 0.3 mg/kg recommended by DUTCH. Mercury, though very useful, can be harmful to humans; it can cause acute and chronic poisoning. Also, exposure to inorganic mercury is said to cause type 2 diabetes in humans. Arsenic had the second-lowest value among the studied metals.

Table 1: Heavy metal distribution in the studied soils and control plot

Metals	SS1 (Mg/Kg)	SS2 (Mg/Kg)	Mean (Mg/Kg)	SD	CV (%)	SSC (Mg/Kg)	RL (Mg/Kg)
Pb	2.422	1.835	2.129	0.415	19.501	0.862	[1,2]85.000
Hg	<0.001	<0.001	<0.001	0.000	0.000	<0.001	[1]0.300
Co	0.452	0.084	0.268	0.260	97.095	0.009	[1]9.000
V	0.034	0.123	0.079	0.063	80.169	0.007	[1]42.000
As	0.003	0.012	0.008	0.006	84.853	0.002	[1]29.000
Fe	41.214	28.305	34.760	9.128	26.261	17.114	[2,4]400.000
Cu	6.187	5.216	5.702	0.687	12.042	3.927	[1,2]36.000
Cd	3.469	2.702	3.086	0.542	17.577	1.684	[3]7.000
Cr	0.104	0.424	0.264	0.226	85.710	0.831	[1,2,4]100.000
Mn	0.547	0.685	0.616	0.098	15.841	0.345	[4]200.000
Ni	1.626	2.102	1.864	0.337	18.057	1.114	[1,2]35.000
Zn	15.104	18.313	16.709	2.269	13.581	14.102	[1,2]140.000

Key: SS1= Soil sample-1 (Itu), SS2= Soil sample-2 (IK), SSC= Soil sample control, SD= Standard deviation, CV= Coefficient of variation, RL= Recommended limits of DUTCH[1], FEPA[2], WHO/FAO[3] and NESREA[4].

Concentrations of 0.003 mg/kg and 0.012 mg/kg of arsenic were observed in the Itu and Ikot Ekpene abattoirs, respectively. The 84.853% CV obtained shows a very high variation in the values of both abattoirs. The mean value of 0.008±0.006 mg/kg was obtained. This value was lower than the 29 mg/kg permissible limit by DUTCH. The concentrations of Zn in the Itu and Ikot Ekpene abattoirs were 15.104 mg/kg and 18.313 mg/kg, respectively. Zn showed a slight variation of 13.581% between both abattoirs. The mean value was 16.709±2.269 mg/kg; this value was higher than the 1.302–5.236 mg/kg reported by Ubwa *et al.* (2013) but similar to the result obtained by Simeon & Friday (2017). The mean value was higher than the 14.102 mg/kg obtained from the control plot but lower than the 140 mg/kg permissible limits by DUTCH and FEPA. The possible sources of Zn on abattoir soils are zinc-containing feed supplements, which are deposited through excretion by animals. They can also come from waste materials and zinc-plated tools used in the abattoir. The result showed concentrations of Cr of 0.104 mg/kg for Itu and 0.424 mg/kg for Ikot Ekpene abattoirs. Chromium showed a very high variation of 85.710% between values from both abattoirs. The mean value obtained was 0.264 ± 0.226 mg/kg. This value was similar to the average value of 0.210 ± 0.050 mg/kg obtained by Ebong *et al.* (2020). The mean value was below the 100 mg/kg of DUTCH, FEPA, and NESREA permissible limits. Dung *et al.* (2013) reported that chromium can easily leach from the soil to surface waters by surface runoff, and it can be absorbed from the soil into the groundwater. The result revealed a concentration of 1.626 mg/kg for Itu and 2.102 mg/kg for Ikot Ekpene abattoirs. Nickel showed a slight variation of 18.057% between both abattoirs. The mean value obtained was 1.864±0.337 mg/kg, which was less than the 75.45 mg/kg obtained by Ande *et al.* (2015). The mean value was greater than the 1.114 mg/kg obtained in the control plot but less than the 35 mg/kg permissible limit of DUTCH and FEPA. Nickel can contaminate abattoir soil through excreters, which then percolate into the soil. 3.469 mg/kg and 2.702 mg/kg of cadmium were obtained from the Itu and Ikot Ekpene abattoirs, respectively. Cadmium showed a slight variation of 17.577%. The mean concentration was 3.086±0.542 mg/kg, which was greater than the 1.684 mg/kg obtained in the control plot but less than the 7 mg/kg recommended limits of FAO/WHO. The mean value was greater than the 0.0035–0.0660 mg/kg reported by Ubwa *et al.* (2013). Although cadmium concentrations can reach up to 3 mg/kg without anthropogenic activities, this concentration can be harmful to humans. The concentrations of Co in the Itu and Ikot Ekpene abattoirs were 0.452 mg/kg and 0.084 mg/kg, respectively. The control soil had the lowest concentration of 0.009 mg/kg.

The results obtained from both abattoirs varied significantly (97.095%) from each other, with a mean value (0.268±0.260 mg/kg) below the 9 mg/kg DUTCH permissible limit. The mean value was lower than the 13.2–30.02 mg/kg obtained by Yahaya *et al.* (2009). The results obtained for manganese were 0.547 mg/kg and 0.685 mg/kg for Itu and Ikot Ekpene abattoirs, respectively. The values from both abattoirs showed a slight variation of 15.841%. The mean value was 0.616±0.098 mg/kg; this value was greater than the 0.345 mg/kg obtained from the control plot but less than the 200 mg/kg recommended limit of NESREA. The results obtained were less than the 249.72–561.03 mg/kg obtained by Yahaya *et al.* (2009). Vanadium concentrations of 0.034 mg/kg and 0.123 mg/kg were obtained for the Itu and Ikot Ekpene abattoirs, respectively. A very high variation of 80.169% was observed in the results for both abattoirs. A mean concentration of 0.079±0.063 mg/kg was obtained; this value was less than the 42 mg/kg recommended limit of DUTCH.

Generally, the distribution of heavy metals in the Itu abattoir was of the order Hg < As < V < Cr < Co < Mn < Ni < Pb < Cd < Cu < Zn < Fe, while that of the Ikot Ekpene abattoir was Hg < As < Co < V < Cr < Mn < Pb < Ni < Cd < Cu < Zn < Fe. The mean order obtained for both abattoirs was Hg < As < V < Cr < Co < Mn < Ni < Pb < Cd < Cu < Zn < Fe. From the order highlighted above, it is noted that the essential metals are higher in concentration compared to the metals with little or no biological use.

Pollution Assessment: Contamination factor (CF): Contamination factor was employed to determine the level of soil contamination in the study areas. Calculations was done using equation 1. The values for the analyzed metals in the Itu abattoir ranged from 0.000 to 0.496, and the contamination sequence observed was As < V < Cr < Mn < Hg < Pb < Ni < Co < Fe < Zn < Cu < Cd. Similarly, 0.000 to 0.386 was obtained in the Ikot Ekpene abattoir, and the sequence observed was As < V < Hg < Mn < Cr < Co < Pb < Ni < Fe < Zn < Cu < Cd. The mean range obtained from both abattoirs was 0.000 to 0.441 with the metal sequence of As < V < Cr < Mn < Hg < Pb < Co < Ni < Fe < Zn < Cu < Cd. Based on the classification of Hakanson (1980), all values of the contamination factor were < 1, which indicates low contamination.

Table 2: Summary of contamination factor, geo-accumulation index and degree of contamination of the study areas

	CF		I_{geo}	
Metals	**SS1**	SS2	**SS1**	**SS2**
Pb	0.028	0.022	-5.718	-6.119
Hg	0.003	0.003	-8.814	-8.814
Co	0.050	0.009	-4.900	-7.328
V	0.001	0.003	-10.856	-9.001
As	0.000	0.000	-13.824	-11.824
Fe	0.103	0.071	-3.864	-4.406
Cu	0.172	0.145	-3.126	-3.372
Cd	0.496	0.386	-1.598	-1.958
Cr	0.001	0.004	-10.494	-8.467
Mn	0.003	0.003	-9.099	-8.775
Ni	0.046	0.060	-5.013	-4.642
Zn	0.108	0.131	-3.797	-3.519
$\mathbf{C_{deg}}$	**1.012**	**0.838**		

Geo-accumulation index (I_{geo}): The geo-accumulation index was used to assess the level of metal accumulations in the studied abattoirs. The calculations was done using equation 2. The values for the analyzed metals in the Itu abattoir ranged from -13.824 to -1.598, and the contamination sequence observed was As < V < Cr < Mn < Hg < Pb < Ni < Co < Fe < Zn < Cu < Cd. For the Ikot Ekpene abattoir, -11.824 to -1.958 were obtained, and the sequence observed was As < V < Hg < Mn < Cr < Co < Pb < Ni < Fe < Zn < Cu < Cd. The mean range obtained from both abattoirs was -12.824 to -1.778 with the metal sequence of As < V < Cr < Mn < Hg < Co < Pb < Ni < Fe < Zn < Cu < Cd. According to the classification by Muller (1969), all values of the geo-accumulation index belong to Class 0 of Igeo ≤ 0. Thus, the abattoir soils were uncontaminated.

Degree of contamination (C_{deg}): The degree of contamination was calculated using equation 3. From the values obtained, there is almost no significant difference in the Cdeg values for both abattoirs. In the Itu abattoir, 1.012 was obtained, and 0.838 was obtained in the Ikot Ekpene abattoir. Based on the classifications of the degree of contamination highlighted by Kowalska *et al.* (2016), the values obtained for each of the abattoir soils indicate a low degree of contamination.

Pollution load index (PLI): This index was used to assess the level of deterioration of the soil as a result of the accumulation of heavy metals. Equation 4 was used for the calculations. The results obtained is shown in Table 3 below.

Table 3: General classification of pollution load index of the study areas

Location	PLI
SS1	0.014
SS2	0.016
Mean	0.015
SD	0.002

Conclusion: The investigation revealed that the heavy metals' concentrations in the abattoir soil were higher than the values obtained from the control but lower than their respective permissible limits. Several pollution indices such as pollution assessments contamination factor, geo-accumulation index, degree of contamination, and pollution load index were employed for the analysis. All indices employed depict no pollution. The study areas have low level of pollution for the studied metals. Nonetheless, the abattoirs should be monitored periodically by environmental agencies in order to prevent contamination in the future.

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